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On factors influencing underground space development and utilization in urban centers

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ABSTRACT

This study analyzes factors influencing underground space development and utilization in urban centers, which will play an important role in ensuring that the development of underground space resources in China urban centers is scientific, rational and effective. In this paper, the author points out that climate, geological conditions, economy, metro, important historical events and laws and regulations are important factors influencing underground space development and utilization in urban centers; systematically analyzes the functional mechanism of each factor and carries out case studies; puts forward the concept of development coefficient, which is used to evaluate all the factors' comprehensive influence on underground space development and utilization in urban centers; focuses on establishing an analysis and evaluation model of comprehensive influence from all factors; suggests to use development coefficient to evaluate underground space development and utilization level in urban centers; quantifies the effect of each factor on underground space development in urban centers through model calculation; makes calculations by using actual data obtained in Nanjing Xinjiekou, and gets the final evaluation results of underground space development level in Xinjiekou.

Key words: Urban Centers; Underground Space; Influence Factor; Development Coefficient; Evaluation Model

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INTRODUCTION

At present, there are great disparities in the development and utilization of underground space resources in different cities in China. Among the cities that have developed their underground space, most are confined to decentralized construction of individual projects and only lay emphasis on individual benefit. As a result, underground space planning lags behind, leading to the fact that over-ground space planning is completely divorced from underground space planning, thus wasting more space resources which are already rare in quantity.

Against this background, to study factors influencing underground space development and utilization in urban centers will be of great importance in ensuring that the development of underground space resources in China urban centers is scientific[1] rational and effective.

The research object is the factors influencing underground space development and utilization in urban centers. Underground space in urban centers mainly refers to underground public activity space and traffic space in urban centers, including underground business, cultural and recreational facilities, underground walkways and underground parking etc. Underground space development in urban centers is a complicated process and it can be influenced by many factors, such as natural factors including climate, geological conditions and non-natural factors including politics, economy, culture ideology, population density, surface building capacity, traffic, important historical events, laws and regulations and technology[2]. It covers a wide range of areas, therefore, based on study of several successful cases about underground space development in urban centers, this research focuses on six factors: climate, geological conditions, economy, important historical events, metro and laws and regulations. The effect of each factor on underground space development in urban centers and their functional mechanism are analyzed. In this way, the factors influencing underground space development and utilization in urban centers are analyzed in a systematic way, thus ensuring that the development of underground space resources in China urban centers is scientific, rational and effective.

STUDY OF DEVELOPMENT COEFFICIENT OF COMPREHENSIVE INFLUENCE FACTOR OF UNDERGROUND SPACE DEVELOPMENT IN URBAN CENTERS

2.1 Definition of Development Coefficient

Effect of the six factors (climate, geological conditions, economy, important historical events, metro and laws and regulations) on underground space development in urban centers is a consequence of their combined action. These factors interact with each other and condition each other, resulting in a complicated comprehensive influence factor. The effect of this comprehensive influence factor on urban centers underground space development stands for the development level [3]. To facilitate quantitative calculation, development coefficient is used an index to evaluate the development level. Development coefficient equals the ratio between total volume of underground space development in a region and the area of this region under the same unit of measure [4]. It is a dimensionless index. Larger development coefficient means that underground space has higher development level and more development potential.

2.2 Establishment of Comprehensive Influence Factor Analysis Model

To quantify the effect of each factor in macroscopic scope, this paper, on the basis of quantification theory, establishes a comprehensive influence factor of urban centers underground space development, namely development coefficient analysis and evaluation model. Factors influencing the development coefficient are categorized into 6 types: climate, geological conditions, economy, metro, important historical events and laws and regulations. Each type of factors contains several items.

Factor 1: climate, 2 items: ordinary or awful;
Factor 2: geological conditions, 2 items: good or ordinary;
Factor 3: economy, 2 items: per capita income below 40,000 RMB or above 40,000 RMB;
Factor 4: metro, 2 items: with or without metro;
Factor 5: important historical events, 2 items: without important historical events in recent period or with important historical events in recent period;
Factor 6: laws and regulations, 2 items: unsound or relatively sound.

Each factor will have varying degrees of effect on urban centers underground space development coefficient. The weight coefficient of each factor is determined according to quantification theory, so that the evaluation value of development coefficient can be expressed as a linear combination of all the factors' weights and characteristic values, namely:

$$\alpha_p = \sum_{i=1}^{\eta_i} \sum_{j=1}^{\mathrm{K}_j} f_{ij}\delta_{ij} \quad (1)$$

In the expression, α is the evaluation value of development coefficient; f_{ij} is the weight of Item j in Factor i ; δ_{ij} is the characteristic value of Item j in Factor i . The value is assigned as 1 if belonging to the factor, or is assigned as 0 if not; k_i is the number of term of Factor i ; η_i is the class number of factors influencing the development coefficient.

This expression is the final development coefficient analysis and evaluation model. It is obvious that the key point in the model establishment lies in how to decide the weights.

2.3 Determination of Weights

Weight is used to measure the effect of each item on the development coefficient. If we calculate the weight based on the actual statistics, we can regard that the underground space development of the selected urban centers is undergoing continuous development under the influence of the above 6 types of factors [5]. After getting large quantities of statistic data, we can start to determine the weights.

Several cities are randomly selected as samples, for example, *n* cities, β_p (*p*=1,2,……,*n*).

According to Expression (1), we can obtain the theoretical evaluation value α_p of the development coefficient for each city. It can be expressed as:

$$\alpha = \sum_{i=1}^{\eta_i} \sum_{j=1}^{K_j} f_{ij}\delta_{ij}$$

(p=1,2,……,n) (2)

in which, f_{ij} is the weight to be calculated in Expression (1); δ_{ij} is the characteristic value of City *p*, namely:

$$\delta_{pij} = \begin{cases} 1 & \text{Item } j \text{ in Factor } i \text{ of City } p \text{ is positive} \\ 0 & \text{Item } j \text{ in Factor } i \text{ of City } p \text{ is negative} \end{cases} \quad (3)$$

We calculate the least square estimation of f_{ij} according to the principle of least squares in order to obtain the minimal value of the following expression:

$$q = \sum_{p=1}^{n} \varepsilon_i^2 = \sum_{p=1}^{n} \left(\beta_p - \sum_{i=1}^{\eta_i} \sum_{j=1}^{k_j} f_{ij}\delta_{pij} \right)^2$$

Therefore, we calculate the partial derivative of *q* with respect to f_{lm} and make it equal to 0, so we can obtain the following:

$$\frac{\partial_q}{\partial f_{lm}} = -2\sum_{p=1}^{n} \left(\beta_p - \sum_{i=1}^{\eta_i} \sum_{j=1}^{k_j} f_{ij}\delta_{pij} \right) \delta_{plm} = 0 \quad \begin{cases} l = 1, 2, \cdots, \eta_j \\ m = 1, 2, \cdots, k_j \end{cases} \quad (4)$$

As long as we make the expression clear, we can get a system of linear equations with f_{ij} as unknown.

$$\sum_{p=1}^{n} \sum_{i=1}^{\eta_i} \sum_{j=1}^{k_j} f_{ij}\delta_{pij}\delta_{plm} = \sum_{p=1}^{n} \beta_p \delta_{plm} \quad \begin{cases} l = 1, 2, \cdots, \eta_j \\ m = 1, 2, \cdots, k_j \end{cases} \quad (5)$$

As long as we solve the system of equations, we can obtain the value of f_{ij}, so that the analysis and evaluation model is completely determined.

2.4 Model Verification

After the calculation of least square estimation, the model can be verified using the multiple correlation coefficient $\gamma_{\alpha\beta}$ (namely the sample correlation coefficient between α and β). It can be calculated as:

$$\gamma_{\alpha\beta} = \sqrt{\frac{\sum_{p=1}^{n} \left(\alpha_p - \overline{\beta} \right)^2}{\sum_{p=1}^{n} \left(\beta_p - \overline{\beta} \right)^2}} \quad (6)$$

In this expression, larger $\gamma_{\alpha\beta}$ means better accuracy of the model.

Three methods can be used to measure the effect of each factor on development coefficient: coefficient of partial correlation, variance ratio and scope [6]. As a matter of experience, variance ratio is the most suitable method. Therefore, variance ratio is used in this research to verify the effect of each factor on development coefficient:

$$\frac{\sigma_i^2}{\sigma_\beta^2} = \frac{\sum_{p=1}^{n} \left(\alpha_p - \overline{\alpha} \right)^2}{\sum_{p-1}^{n} \left(\beta_p - \overline{\beta} \right)^2} \quad i = 1, 2, \cdots \eta_i \quad (7)$$

In the expression, $\alpha_p = \sum_{j=1}^{k_j} f_{ij}\delta_{pij}$ ($p=1,2,\cdots,n; i=1,2,\cdots,\eta_i$) is the quantitative data of Factor *i* in City *p*.

PRACTICAL CALCULATION

3.1 Model Calculation

In this paper, relevant data from 12 urban centers are selected as the calculation sample including Beijing Wangfujing, Shanghai Jing'an Si, Shenzhen CBD [7], Hangzhou Qianjiang New District CBD, Zhengzhou Zhengdong New District CBD, Beijing Zhongguancun[8], Quzhou New District CBD, Qingdao CBD, Yiwu international business district, Tangshan airport core area[9], Wuhan Wangjiadun business center and Hangzhou Binjiang CBD (Table 1) [10]. Then we can obtain the share of each factor in China urban center underground space development. On this basis, the author takes Nanjing Xinjiekou as an example to calculate the evaluation value of development coefficient and decide the development level here.

First, according to the above steps, we can calculate the weights f_{ij} through programming. Then we substitute them in Expression (1) and get the final analysis and evaluation model of development coefficient:

$$\alpha = 0.0\delta_{11} + 0.2854486\delta_{12} + 0.083395\delta_{21} + 0.0\delta_{22} + 0.4569667\delta_{31} + 0.0\delta_{32}$$
$$+0.0\delta_{41} + 0.141607\delta_{42} + 0.0\delta_{51} + 0.149734\delta_{52} + 0.0\delta_{61} + 0.076442\delta_{62} \quad (8)$$

In the expression, $\delta_{1j},\delta_{2j},\delta_{3j},\delta_{4j},\delta_{5j},\delta_{6j}$ stand for the characteristic values of climate, geological conditions, economy, metro, important historical events and laws and regulations respectively.

Table 1 Relevant Data from 12 Chinese Cities

City	Climate	Geological Conditions	Economy (Per Capita GDP: yuan)	Metro	Important Historical Events	Laws and Regulations	Development Coefficient
Beijing Wangfujing	awful	good	58204	with	with	relatively sound	0.36
Shanghai Jing'an Si	ordinary	good	66367	with	with	relatively sound	0.87
Shenzhen CBD	awful	good	79645	with	without	unsound	0.58
Hangzhou Qianjiang New District CBD	ordinary	ordinary	61258	with	without	relatively sound	0.52
Zhengzhou Zhengdong New District CBD	ordinary	good	40617	with	without	unsound	0.8
Beijing Zhongguancun	awful	good	58204	without	with	relatively sound	1
Quzhou New District CBD	awful	ordinary	15740	without	without	unsound	0.14
Qingdao CBD	ordinary	ordinary	38892	with	with	unsound	0.63
Yiwu international business district	ordinary	good	59144	without	without	unsound	0.95
Tangshan airport core area	awful	ordinary	37734	without	without	unsound	0.24
Hangzhou Binjiang CBD	ordinary	ordinary	61258	with	without	relatively sound	1.15
Wuhan Wangjiadun business CBD	awful	ordinary	35500	with	without	unsound	0.35

3.2 Model Test

The multiple correlation coefficients can be calculated using Expression (6) as:

$$\gamma_{\alpha\beta} = \sqrt{\frac{\sum_{p=1}^{20}\left(\alpha_p - \bar{\beta}\right)^2}{\sum_{p=1}^{20}\left(\beta_p - \bar{\beta}\right)^2}} = 0.85 \quad (9)$$

From this we know that the calculation accuracy of development coefficient is high.

Through Expression (7), we can obtain the variance σ_i^2 and variance ratio $\sigma_i^2/\sigma_\beta^2$ of each factor (Table 2).

Table 2 Variance and Variance Ratio of Each Factor

Influence Factor	σ_i^2	$\sigma_i^2/\sigma_\beta^2$
climate	0.0395	0.2926
geological conditions	0.0146	0.1081
economy	0.0613	0.4541
metro	0.0253	0.1874
important historical events	0.0289	0.2141
laws and regulations	0.0107	0.0793

Model variance test shows that six factors have varying degrees of effect on development coefficient. Among these factors, economy is the most influential one, followed by climate. Important historical events and metro have relatively obvious effect while laws and regulations and geological conditions have the least effect on underground space development [11].

3.3 Evaluation of Underground Space Development in Xinjiekou

If we substitute relevant data from Nanjing Xinjiekou (i.e. characteristic values shown in Table 3) into Expression (8) [12], we can get:

$$\alpha = 1.025667$$

Table 3 Characteristic Values in Nanjing Xinjiekou

climate	δ_{11}	0	metro	δ_{41}	0
	δ_{12}	1		δ_{42}	1
geological conditions	δ_{21}	0	historical events	δ_{51}	0
	δ_{22}	1		δ_{52}	1
economy	δ_{31}	1	laws and regulations	δ_{61}	1
	δ_{32}	0		δ_{62}	0

From Expression (8), we can know the maximal value of development coefficient is 1.19 and that development coefficient of underground space development in Xinjiekou is 1.025667. Therefore, we can say that development level of underground space in Xinjiekou is high and there is also huge potential for further development here.

CONCLUSION

In this research, the author puts forward the concept of underground space development coefficient; measures the comprehensive effect of various factors on underground space development in urban centers by using development coefficient; uses quantification theory to establish the analysis and evaluation model of underground space development coefficient; carries out calculations using relevant data from 12 urban centers in China; quantifies the effect of six types of factors on urban centers underground space development and comes to a conclusion that economy is the most influential factor, followed by climate[13]. Important historical events and metro have relatively obvious effect while laws and regulations and geological conditions have the least effect on underground space development. Finally, the author makes calculations by using relevant data from Nanjing Xinjiekou and obtains the evaluation results of underground space development in Xinjiekou.

REFERENCES

[1] Chen, Zhilong, Wang, Yubei The Urban Underground Space Planning, vol. 1, first ed. Southeast University Press, Nanjing, **2005** (in Chinese).

[2] Gao, Dongmei. *Architecture Journal*, Vol. 5, pp.66–68 , **2004** (in Chinese).

[3] Gideon S.G. et al. The Urban Underground Space Design, vol. 1. China Building Industry Press, Beijing,**2005**.

[4] Hu, Hao.. Report of Real Estate Development 2007 in Shanghai. Shanghai Jiao Tong University Press, **2007** (in Chinese)..

[5] Ma, Shi, Shu, Yu. The Research on Forecasting Demand of Urban Underground Space Development and Utilities in the case of Shanghai. Master Degree Thesis, Tongji University, Shanghai , **2007** (in Chinese).

[6] Mao, Fengfu The empirical research on the relationship between house price and land price 1999–2004. In: Chinese Economic Association 2006 Annual Meeting , **2006**. (in Chinese).

[7] Monnikhof, R.A.H. et al.. *Tunnelling and Underground Space Technology,* Vol. 14 (3), pp.341–347**, 1999**.

[8] Shu, Yu.. Underground Space and the Future City. Fudan University Press,Shanghai **, 2005** (in Chinese).

[9] Bobylev, N.. *Land Use Policy* ,Vol. 26 (4), pp.1128–1137**, 2009**.
[10] Xu, Guoqiang, et al.. The Research on Forecasting Demand of Urban Underground Space Development and Utilities Based on The Harmony Development Theory. Urban Planning Forum **, 2008** (in Chinese).
[11] Sellberg, B.. *Tunnelling and Underground Space Technology* . Vol.11 (4), pp.369–371**, 1996**.
[12] ITA WG 13. *Tunnelling and Underground Space Technology.* Vol.1110(3), pp.287–297, **1995**.
[13] Qiuliang Shu, Yu Shu. *Chinese Journal of Underground Space and Engineering*, Vol. 6(4), pp. 661-665, **2010**.